PCT WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : B09C 1/00, 1/08, 1/10 | A1

(11) International Publication Number: WO 97/13593

(43) International Publication Date: 17 April 1997 (17.04.97)

(21) International Application Number: PCT/US96/10499

(22) International Filing Date: 2 July 1996 (02.07.96)

(30) Priority Data:
08/537,991 29 September 1995 (29.09.95) US

(71)(72) Applicants and Inventors: SUCHECKI, Ronald, J., Jr. [US/US]; 911 Black Diamond Circle, Hewitt, TX 76643 (US). BURTON, Dudley, J. [US/US]; 1197 Western Oaks, Waco, TX 76712 (US).

(81) Designated States: CA, MX, European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published
With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: A METHOD FOR INTRODUCING MATERIALS INTO A SOLID OR SEMI-SOLID MEDIUM

(57) Abstract

It is an object of the present invention to provide a novel means for introducing materials, such as organisms, chemicals, bio-active chemicals, and inert materials, into a contaminated madium, by means of a sudden burst of gas.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AM	Armenia	GB	United Kingdom	MW	Malawi
AT	Austria	GE	Georgia	MX	Mexico
AU	Australia	GN	Guinea	NE	Niger
BB	Barbados	GR	Greece	NL	Netherlands
BE	Belgium	HU	Hungary	NO	Norway
BF	Burkina Faso	IE	Ireland	NZ	New Zealand
BG	Bulgaria	IT	Italy	PL	Poland
BJ	Benin	JP	Japan	PT	Portugal
BR	Brazil	KE	Kenya	RO	Romania
BY	Belarus	KG	Kyrgystan	RU	Russian Federation
CA	Canada	KP	Democratic People's Republic of Korea	SD	Sudan
CF	Central African Republic			SE	Sweden
CG	Congo	KR	Republic of Korea	SG	Singapore
CH	Switzerland	KZ	Kazakhstan	SI	Slovenia
CI	Côte d'Ivoire	LI	Liechtenstein	SK	Slovakia
CM	Cameroon	LK	Sri Lanka	SN	Senegal
CN	China	LR	Liberia	SZ	Swaziland
CS	Czechoslovakia	LT	Lithuania	TD	Chad
CZ	Czech Republic	LU	Luxembourg	TG	Togo
DE	Germany	LV	Latvia	TJ	Tajikistan
DK	Denmark	MC	Monaco	TT	Trinidad and Tobago
EE	Estonia	MD	Republic of Moldova	UA	Ukraine
ES	Spain	MG	Madagascar	UG	Uganda
FI	Finland	ML	Mali	US	United States of America
FR	France	MN	Mongolia	UZ	Uzbekistan
GA	Gabon	MR	Mauritania	VN	Viet Nam

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

TITLE: A METHOD FOR INTRODUCING MATERIALS INTO A SOLID OR SEMI-SOLID MEDIUM

INVENTORS: DUDLEY J. BURTON AND RONALD J. SUCHECKI JR.

BACKGROUND OF THE INVENTION

1. Field of the Invention

Applicant's invention relates to the field of environmental remediation of contaminated sites, and more specifically to the remediation of potentially, environmentally threatening contaminants, such as, but not limited to, hydrocarbons, man made chemicals, or naturally occurring contaminants that are dangerous to human health.

2. Description of the Prior Art

Environmental pollution and contamination is one of the greatest threats facing modern society. Environmental contamination invades the water supply for both humans and the other populations on which humans rely. In dump sites and other storage facilities toxic pollutants emit noxious chemicals, liquids, gases, and other substances which can injure or even cause death to humans and the other populations. There are numerous sources of environmental pollution including the disturbance of naturally occurring deposits of toxic materials as well as a long list of contaminants introduced into the environment by human neglect, waste, dumping, or mismanagement. Some of these contaminants can be identified as motor oil and other petroleum based products, including gasoline, kerosene, diesel, hydraulic fluid, synthetic oils, other lubricating materials, and BTEX components; paints, paint thinners, and other volatile organic compounds; corrosive and deadly materials, such as chromium, arsenic, radio-active materials, and all other RCRA listed chemicals, compounds, and materials.

Environmental contaminants exist in either soil, water, some other medium, or a combined medium. A soil is best defined as actual dirt, clay, and other naturally occurring earthen substances. Soil is usually found in, at, or near storage containers for contaminants, both above and below the surface, industrial manufacturing and development locations, and other locations where contaminants are used, made, stored, or otherwise exposed to the environment. A medium is any manmade solid or semi-solid substance where environmental contaminants can exist. A medium includes, for example, solid-waste disposal sites, such as dumps, where human garbage and trash is buried, compressed, or stored, man-made storage and containment substances, such as f am, sludge, gels,

and ther substances, and other more solid, permanent containment fields, such as concrete and cement.

In an attempt to prevent and remedy the detrimental effects f these environmental contaminants, two primary strategies have been implemented: ex-situ remediation and in-situ remediation. Ex-situ remediation consists of physically extracting the soil or other medium from the surrounding earth or under-ground location, treating the extracted soil or medium, and then replacing it into the surrounding earth. In-situ remediation attempts to treat and neutralize the contaminants that are latent within the soil or medium without physically extracting the contaminated soil or medium. The general practice of both ex-situ and in-situ remediation only attempts to treat the contaminants found in soils and does not attempt to treat the contaminants found in the other media. As a result, the following analysis of the prior art describes the most common ex-situ and in-situ remediation techniques for treating contaminated soils.

Ex-situ remediation by definition involves the removal of the contaminated soil from its native environment, treatment of the removed soil by either a physical or chemical means, and then a return of the soil to its original locus. After removing the soil, the common practice is to place or store the unearthed, contaminated soil in either a sealed or open air volatilization area for treatment. After treatment or simply removal from the contaminant's original location, the treated soil is either returned to its source or it is stored or buried in a hazardous waste landfill or containment area, where future liability exists indefinitely. If the contaminated soil is removed and not returned to its original removal site, then other soil must be found to fill the void that is left behind. Currently, ex-situ remediation utilizes several methodologies: Thermal Desorption, Thermal Destruction, Incineration, Stabilization, Solidification, Soil Washing, Chemical Treatment, Biological treatment, Land Farming, and other viable methods.

Because of the high costs of transportation, the potential impossibility of removal, and the damage inflicted on the land from which the soil is removed, as well as other negative factors, the in-situ theory and methodology has usurped the ex-situ theory and method of remediating contaminated areas.

In some situations, in-situ remediation has proved to be a more cost-effective and reliable method for remediating environmentally contaminated solid than any f the ex-situ methods, if and

when it can be achieved. Generally, the goal of in -situ remediation is to neutralize or remedy the deleterious human and environmental effects of contaminated soils. The most prominent and advanced methods of in-situ remediation include Vitrification, Stabilization, Solidification, Soil Flushing, Air-Sparging, Free Product Recovery, Chemical Treatment, Electroosmosis, Vacuum Vapor Extraction, Bioremediation, Bio Venting, Hydraulic Fracturing, and Pressurized Pneumatic Fracturing.

Vitrification is a process used for stabilizing soils or sludge contaminated with radioactive, metallic, or certain organic wastes, whereby they are made "glass like." Vitrification can be performed in-situ or in special refractory liners. To perform in-situ vitrification, a mixture of ground glass frit and graphite flakes are inserted below the surface of the soil between 4 electrical probes. Electrical voltage is then applied to the electrodes which heats the surrounding soil and mixture, causing the mixture and the soil to melt. Once molten, the soil begins to conduct electrical current and the graphite is consumed by oxidation. The molten soil grows outward and downward until the desired vitrification depth is obtained. However, this electrical vitrification has two primary drawbacks: first, vitrification only seals the contaminant below the surface in a permanent form which cannot be removed or recovered and second, vitrification can only be performed to a contaminant twenty (20) feet or less beneath the surface.

Stabilization, as a broad categorization, includes different processes which attempt to make the environmental contaminants less soluble, mobile, or toxic and thus reduce the potential human and environmental risks caused by the contaminants. Stabilization can be achieved by changing pH, moisture contents, or chemical matrix. Although stabilization can neutralize some contaminants, the chemical nature of the waste is not necessarily changed.

Solidification refers to processes that encapsulate the contaminant into a monolithic solid of high-structural integrity. Solidification includes two primary classifications: microencapsulation, where small contaminated areas are solidified, and macro-encapsulation, where large areas of contamination are solidified. Solidification does not necessarily involve a chemical interaction between the contaminant and the solidifying reagents, but may mechanically bind the waste into the monolith. Contaminant migration is restricted by vastly decreasing the surface area exposed to a leaching area r by isolating the waste within an impervious capsule.

Soil Flushing attempts to enhance the mobilization r ability or the contaminants to move within a soil, so that the contaminant can be recovered or treated. Soil flushing uses water, enhanced water, mixtures (surfactants), r gaseous mixtures to accelerate ne or more of the same geochemical dissolution reactions that alter contaminant concentrations in ground water systems. Soil flushing has two primary applications: one, the recovery of mobile degradation products which are formed after the soil has been treated with chemical oxidizing agents and two, oil recovery operations. Soil flushing is most effective in sandy soils and its effectiveness is dependent on the matrix as well as the organic, inorganic and contaminant composition of the soil or medium in which it is used.

Air sparging is accomplished by injecting air under pressure below the soil surface. Air sparging strives to volatilize and biodegrade the contaminants located within the air-flow pathways latent within the soil. Also, air-sparging potentially allows the dissolved phase contaminants that contact the air-flow field to volatilize or biodegrade. Air Sparging extends the utility of "soil vapor extraction." The primary draw-back to air-sparging is that once air is injected into the saturated zone, its flow is primarily governed by the applied pressure, buoyant forces, vertical and horizontal permeability distributions in the saturated zone, and the capillary properties of the soils. In short, air-sparging does not create new "air-flow zones" into which the contaminants can flow, volatolize, and biodegrade, but instead relies on the naturally occurring air-flow passageways.

The Basic Free Product Recovery system is a very simple means of recovering large quantities of free product, which is any type of spilled, leaked, or naturally occurring pools of potentially environmentally threatening contaminants in liquid form. In the usual basic free product recovery method a well is drilled into the ground which provides a low pressure space into which any existing "free product" can escape. This is an effective method for removing large quantities of liquids; however it has little or no effect on products which are not "free". One major draw-back to this process is that products which are not free but are bound in the clays, silts, or other components of the soil matrix, sediments, sludge, or water do not naturally "flow" into these low pressure areas. Moreover, this process in almost all cases must be coupled with other methods of remediation to excise the contaminants that are not free, and thus bring the contamination to acceptable levels.

Chemical treatment systems refer to the use of reagents to destroy or chemically modify target contaminants. These chemical processes are used t treat contaminated soils, ground water, surface water and concentrated contaminants. The use of the chemical treatment method is circumscribed by the innate limitation of chemicals to flow through solid, non-porous soils and media, thus limiting the depth of its application and its effectiveness at reaching the contaminant.

Electroosmosis was developed in the 1930's and has been used to dehydrate clays, silts, and fine sands in road beds, dams, and other engineering structures. The electroosmosis process is based on the fact that clay particles are usually negatively charged and thus attract positively charged ions (cations) to form a layer on the surface of water within the pores of the clay. If an electric field is established using electrodes, cations will migrate toward the cathode, bringing the water along with them. Electroosmosis provides uniform water flow through soils and media, including heterogeneous materials. The direction of water flow is easily controlled via the placement and polarity of the electrodes. Electroosmosis is an inadequate means to eradicate solid contaminants or contaminants that are not ionic.

The Basic Vapor Extraction system combines the use of vapor extraction wells with either blowers or vacuum pumps. Basic Vapor Extraction drills wells, essential air passage ways, and then applies either a blowing or vacuum device to create a flow of contaminant vapor from zones permeable to vapor flow into the extraction wells. Vapor Extraction enhances the volatilization and removal of contaminants from the subsurface for treatment. The vacuum developed in the extraction well draws air from the above the soil atmosphere through the soil, so as to cause the different contaminants to volatolize and release into the moving air. More complex soil vapor extraction systems incorporate trenches, horizontal wells, forced-air injection wells, passive air inlet wells, ground water recovery systems, impermeable surface seals, multiple vapor extraction wells in single boreholes, and various thermal enhancements. The main limitation to the vapor extraction method is that air only moves into the pre-bored vaporization well holes and only those contaminants exposed to the pre-drilled well holes are able to be remediated.

Bioremediation exploits the ability of certain microorganisms, the heterotrophic bacteria and fungi, to degrade hazardous organic materials to innocuous materials such as carbon dioxide, methane, water, in rganic salts, and bi mass. Microorganisms may derive the carbon and energy

required for growth through biodegradati n f rganic contaminants, or, transform more complex, synthetic chemicals through fortuitous co-metabolism. There are two types of Bioremediation which are used: natural and enhanced. Natural Bioremediati n depends on indigen us microbes to degrade contaminants using only nutrients and electron acceptors available in the remediation site. However, biodegradation rates will be less than optimal if the microbes' nutritional and physiological requirements are not met. Enhanced Bioremediation technologies increase biodegradation rates by supplying those nutrients, electron acceptors, or other factors that are rate limiting. Yet, even applying the current methods of in-situ remediation, neither correct nutrients to feed the indigenous microbes nor alien microbes can reach all or even most of the contaminants resident within the soil.

The current uses of bioremediation have been enhanced by utilizing the techniques of "bio-venting." Bio-venting is simply the application and combination of well hole boring and vacuum vapor extraction with the bioremediation methods discussed above. Under natural conditions aerobic biodegradation rates are typically limited by oxygen supply rates in the soil subsurface. The rate of oxygen supply to the subsurface is increased during the course of vapor extraction as air is drawn from the atmosphere into the subsurface. Therefore the enhanced supply of oxygen to the subsurface will increase the rate at which the aerobic biodegradation of contaminants can take place. However, the supply of air is still limited to the number of air-flow channels created by the number of well holes bored and the amount of contaminants and microbes exposed to the air flow.

Another means of in-situ remediation is hydraulic fracturing. Hydraulic fracturing is a technique developed in the oil and gas industry for creating openings in the soil subsurface. Hydraulic fracturing is accomplished by applying a high-pressure slurry of water or some liquid into the subsurface to create a lateral, pancake-shaped space in low -permeability zones. Sand in the slurry remains in the fracture, supporting it and keeping it open. Hydraulic fracturing is limited in its application because it can utilize only microbes that can live in the liquid or rely thereon.

One of the latest methods applied to in situ remediation is the pressurized pneumatic fracturing method developed by the New Jersey Institute of Technology. The pressurized pneumatic fracturing method relies on a cylindrical probe inserted in the ground for means of transporting a pressurized gas below the surface of the ground for the purpose of pneumatically fracturing the soil. The process used by New Jersey Institute of Technology relies on the slow buildup of pressure to

t fracture the soil. Th desired benefits of the pressurized pneumatic fracturing method is that it sh uld open sub-surface areas int which c ntaminants could fl w and thus v latolize. However, while the pressure and buildup necessary to fracture the soil is being applied, it is a safe scientific inference to believe that the contaminants are actually being pushed into boundaries outside of the original contamination site, the contaminants are being further compacted into the existing soil, and thus frustrating and limiting the recoverability and remediation potential of the contaminant.

SUMMARY OF THE INVENTION

Accordingly, the primary object of the present invention is to provide a new and novel means for conducting in-situ remediation and actually enhancing the known in-situ methods.

It is an object of the present invention to utilize the novel shock-wave effect of the sudden burst of gas to molecularly and physically free the contaminants that are trapped in the media.

It is another object of the present invention to create a novel system of subterranean gas-guiding passages in the media, into which materials can be injected and contaminants can volatilize.

It is yet another object of the present invention to introduce organisms, chemicals, bio-active chemicals, and inert material to remediate the contaminated medium.

It is the final object of the present invention to utilize various gases in the sudden burst to bring about certain reactions in the chemicals, aerobic and anaerobic organisms, and inert materials that are existing or have been injected into the media.

The foregoing objects are achieved in the utilization of the method of the present invention, which enhances remediation by using the shockwave effect, created by the sudden burst of air, to disrupt and fracture the media, thus creating gas-guiding passages into which materials helpful to remediation could by introduced.

BRIEF DESCRIPTION OF THE DRAWINGS

No drawings are required to explain this method.

DETAILED DESCRIPTION OF THE METHOD

The method according to the present inventi n is characterized primarily by the injection and release of an aimed blast of compressed gas int r bel w the surface of the solid r semi-solid medium at a predetermined depth. This method can be applied to numerous types of media, including soil, man-made structures, solidified contaminant masses, sludges, and other media where contaminants exist. To utilize this method a sudden, instantaneous burst is released into the media. This sudden burst causes a shockwave to emenate from the point of release. This shockwave disrupts the physical structure of the media, while the gas that has been directed into the media creates gas-guiding passages. These gas-guiding passages create voids and enable a free-flow within the media for different types of materails. This method allows the practitioner to then utilize the various existing oganisms, chemicals, bio-active chemicals, and inert materials within the structure of the media.

The novel use of a sudden burst of gas to create a shockwave revolutionizes the field of in-situ remediation. Currently, only the New Jersey Institute of Technology (NJIT) has attempted to use any type of gaseous pressure to conduct remediation. The NJIT method is fraught with problems that are deleterious to environmental remediation. First, the NJIT method uses a long, slow build-up of compressed atmospheric air, which eventually causes the ground to fracture. The primary problem with the NJIT slow pressurization method is that it actually compacts the soil and further combines the contaminant with the soil. Second, the NJIT method takes a substantial amount of time to build-up the requisite pressure to cause the fracturing. Third, the most dangerous and hazardous effect of the NJIT slow pressurization method is that it actually forces the contaminants to move outside of the scope of the original contaminated site, into virgin, uncontaminated soil. The present invention suffers none of the maladies of the NJIT method.

The present invention injects at least one sudden burst of gas into the media, which overcomes the limitations of the NJIT method. The raw, physical blast caused by the sudden burst of gas creates a shockwave. A shockwave is an instantaneous disruption created by the presence of more energy on the wave front than the structure which is contacted by the wave can support. Accordingly, when the sudden burst of gas is released, a wave of energy is sent, both

vertically and horizontally, through the medium, which instantaneously moves and disrupts the contaminant and the medium. This shockwave loosens the embedded contaminants and frees the soil, making the contaminated area permeable t gases or remediation agents such as chemicals, bio-active chemicals, organisms, or inert materials. Unlike the NJIT method, the shockwave resulting from the sudden burst of gas rapidly moves through the medium, disrupting the soil only in its place, and does not force the contaminant into new uncontaminated areas. The shockwave caused by the sudden burst of gas creates paths of least resistance within the medium, which serve two purposes: creation of gas guiding passages for the introduction of materials to treat the contaminants and provision of free space into which contaminants can flow so that they can be treated.

Not only does the present invention emit a shockwave which disrupts the matrix and structure of the medium, the sudden burst of gas also creates a novel matrix of gas-guiding passages. When the sudden blast of air is released into the medium, the gas flows into the areas of least resistance and therefore follows the natural structure of the medium and creates voids through which gases could flow and materials could be introduced. The shape and dimension of the gas-guiding passages depends on two primary components: the location and angle of the release of the sudden burst of gas and the composition of the media. The angle of introduction of the gas will determine the angle and positioning of the matrix of gas-guiding passages, which would affect the types of treatments that could be applied to the particular medium. More importantly, however, is the understanding of the composition of the medium. Depending on the type of soil and its structural composition, the specific matrix created by the sudden burst will vary. Thus, a practitioner skilled in the art could determine the angle of introduction of the sudden burst of gas to determined the pattern and shape of the desired matrix of gas-guiding passages, so as to enhance the possible remediation of existing contaminants.

While some practitioners in the prior art make holes in the soil, none are as effective or as thorough as the gas-guiding passages created by the present invention. Practitioners in the prior art have either drilled vertical or horizontal wells, dug up the soil, tilled the soil, or attempted a long pressurized fracture. The physically invasive methods such as drilling, digging, and tilling the soil actually alter the position and integrity of the soil, exposing certain parts to sun light,

partially treating others, and leaving the maj rity f the soil contaminated and untreated. Contrarily, the gas-guiding passages created by the sudden burst f gas and the concomitant shockwave utilizes the naturally occurring fracture lines in the medium to evenly disrupt and aerate the medium. This natural disruption pattern literally tears the medium, loosens the medium structure, and allows a greater amount of materials to reach the contaminants and thus enhance the remediation prospects.

The real result of the present invention is that the soil structure is generally maintained and correspondingly the life of the soil is not affected as is the case with the mechanical means of treating the soil. Moreover the medium is torn according to the pre-defined, naturally occurring breaking lines and is made permeable, thus making the medium thoroughly and deeply aerated, fed, or permeated with oxygen or other desirable gasses.

The present invention is superior to the prior art in that the degree of disruption is controllable. The present invention can be used at differing depths and to differing degrees of fineness. The method according to the invention may be employed for breaking up the medium over wide surfaces in a coarse way as well as for breaking up the medium in a fine narrow mesh manner and is particularly suitable to break up deep-lying compacted zones. This applies to compacted medium of any type and with a moist medium simultaneously brings about a certain flow.

The result of the sudden burst of gas and the concomitant shockwave is a series of gas-guiding passages which can be held open to allow aeration or filled with a suitable material. These passages can be held open with organisms, such as microorganisms including anaerobic and aerobic bacteria, and various classes of fungi; inorganic materials such as absorbents, chemicals, chemical compounds; organic substances such as enzymes, bio-active sludge, cellulose, compost, humus, peat; and inert materials such as sand, diatomaceous earth, Fullers earth, barite, bentonite, polystyrene beads; or similar materials known to those skilled in the art to maintain fissures created by the sudden release of said compressed gas. The introduction of these materials into the gas-guiding passages ensures that these spaces will serve as permeable passageways for water, gases, liquids, and other materials.

Another dramatic improvement over the prior art is the ability of the current method to introduce vari us gasses int the medium to treat and remediate the contaminants. The NJIT method introduces only compressed atmospheric air t create a sl w pressurized lifting and does not consider the ability to bring about certain beneficial results by utilizing the chemical properties of various gasses. The best example of the distinction between the injection of atmospheric "air" and the introduction of a sudden burst of gas is the chemical effect certain gasses have on different organism. If the practitioner were wanting to utilize aerobic micro-organisms, then it would be crucial to supply oxygen to the micro-organisms to enable them to survive and fulfill their purpose. Although atmospheric air contains oxygen, it would be far less effective as a source of energy to the aerobic micro-organisms than would pure oxygen. Also, if the practitioner were to use anaerobic organisms, it would not be desirable to supply oxygen. Thus the injection of atmospheric air would kill or destroy the anaerobic organism, whereas the introduction of carbon dioxide would cause the anaerobic organisms to thrive. This simple example illustrates the revolutionary distinction between the introduction of air and the introduction of a gas.

Once the sudden burst and concomitant shockwave has ruptured the soil and created gas-guiding passages, the practitioner can introduce materials which neutralize, volatilize, or react with the contaminant to make the medium safe to humans and other populations. Although most scenarios would require the practitioner to introduce specialized materials, the gas-guiding passages can be created in a formation, which allows the natural laws of science and physics to remedy the contamination process. Yet, in most situations the following materials would be introduced into the gas-guiding passages: organisms, which consume or disintegrate the contaminant; nutrients, in the form of air or any other compressed gas, which feed and sustain the organisms in the medium, whether naturally occurring or manually introduced; chemicals, which react and stabilize the contaminant; bio-active chemicals which cause certain biological rganisms to respond and destroy or neutralize the contaminant; and inert materials, which would maintain the gas-guiding passages and thus maintain the gas and liquid permeability of the medium. Most importantly the present invention assures that the treatment and thus the contaminant is treated in a hom gen us manner.

The method of the present inventi n can be performed by a relatively simple device. To utilize this method, a devise comprised of a simple introduction means could be made. The introduction means would have at least one outlet orifice, which would be attached to a compressed gas conduit, which would be governed by a simple valve, which would have two settings: open and closed. To utilize the device and exercise this method, the introduction means would be inserted into the medium until it reached the desired depth. Then the compressed gas conduit valve would be opened to release the sudden burst and create the concomitant shockwave. This step could be repeated to introduce not only the desired gases but also the other potential materials: chemicals, bio-active chemicals, organisms, inert materials, as well as those materials discussed above.

Although the invention has been described with reference to specific embodiments, this description is not meant to be construed in a limited sense. Various modifications of the disclosed embodiments, as well as alternative embodiments of the invention will become apparent to persons skilled in the art upon reference to the description of the invention. It is therefore, contemplated that the appended claims will cover such modifications that fall within the scope of the invention.

CLAIMS

I claim:

1. A method of introducing materials int a solid or semi-solid medium, by means of a sudden burst of gas into said medium, the method comprising the steps of:
   a. Injecting said gas into said medium at said predetermined depth below the surface of said medium;
   b. Controlling said injecting step so that gas is released in at least one sudden burst and with sufficient pressure at said predetermined depth to pneumatically erupt the medium and form gas guiding passages; and
   c. Introducing said materials into said passages following said injecting step or simultaneously with said injecting step.
2. The method of Claim 1, wherein the compressed gas is released only at said predetermined depth.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US96/10499

A. CLASSIFICATION OF SUBJECT MATTER
IPC(6) :BO9C 1/00,1/08, 1/10
US CL :166/308; 405/128
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : 166/249, 271, 308; 405/128; 210/747

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
NONE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5,032,042 A (SCHURING ET AL) 16 July 1991 (16.07.91), col. 6, line 16 - col. 7, line 9; col. 11, lines 1-18.	1,2
X	US 5,131,472 A (DEES ET AL) 21 July 1992 (21.07.92), col. 6, lines 8-34; col. 7, line 57 - col. 8, line 20.	1,2
X	US 5,429,191 A (SCHMIDT ET AL) 04 July 1995 (04.07.95), col. 2, lines 1-22	1,2
A, P	US 5,525,008 A (WILSON) 11 June 1996 (11.06.96), see entire document	1,2
A	US 5,265,678 A (GRUNDMANN) 30 November 1993 (30.11.93), see entire document	1,2

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
26 FEBRUARY 1997	18 MAR 1997

Name and mailing address of the ISA/US	Authorized officer
Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231	GEORGE SUCHFIELD
Facsimile No. (703) 305-3230	Telephone No. (703) 308-2168